Chapter III. CHARACTERISTIC ALGAL ASSOCIATIONS AND FORMATIONS AT WOODS HOLE AND IN BUZZARDS BAY AND VINEYARD SOUND.

As stated in the preceding pages, the life habits and distribution of marine algæ are affected by a number of factors, the most important of which are temperature, light, depth, character of the bottom, and salinity of the water. Some or all of these factors, and in special cases others as well, determine, as a rule, the habitats and seasons of the different species. As a result, various algæ are frequently found to be characteristic of particular situations, where they constitute groups or *formations* of species.

J. G. Agardh (1836) was the first to describe regions of algal vegetation, recognizing on the Scandinavian coasts the presence of a zone characterized by green algæ (*Regnum Algarum Zoospermarum*), a zone of brown algæ (*Regnum Algarum Olivacearum*), and a zone of red algæ (*Regnum Algarum Floridearum*). Other authors have attempted similar, but more elaborate, divisions of the algal flora into regions and zones, but none have been very satisfactory for the reason that the brown and red algæ have species which range far outside the depth or zone which is in general most characteristic of their class.

It later became apparent that the algæ must be split into smaller assemblages than the zones of green, brown, and red algæ, and Kjellman (1877 and 1878), also in studies on the Scandinavian coast, developed such a classification in detail, applying the name "formation" to each group and usually naming each formation after the alga most characteristic of it. Kjellman's paper of 1878, "Ueber Algenregionen und Algenformationen im östlichen Skager Rack," stands, as far as the author is aware, as the first algological contribution introducing the methods and terminology of ecology as at present practiced. Later authors have followed the methods of Kjellman to a greater or less degree, and among them one of the most elaborate studies has been that of Börgesen (1905), "The Algæ Vegetation of the Færöese Coasts." The reader will find in these two papers of Kjellman and Börgesen historical treatments of the literature, which need not be repeated here, especially since they deal with conditions in northern waters, which are very different from those at Woods Hole.

Kjellman (1877) employed the terms "littoral,"[a] "sublittoral," and "elittoral" to define three regions of distribution, and these terms are in wide use among botanists and, with certain modifications of his definitions, they have replaced earlier expressions designating regions occupied by the green, the brown, and the red algæ. Kjellman defined the littoral region as that between lowest and highest tide marks, the sublittoral region as that from the lowest tide mark to the furthest depth at which algæ will grow (about 20 fathoms on the Scandinavian coast), and the elittoral region as that bottom below the sublittoral.

[a] Cf. discussion on pages 178–180, section 1, of present report.

Kjellman's limitation of the littoral region has not proved altogether satisfactory, since many marine algæ range far above the highest tide mark, especially along coasts wet by the spray from heavy surf, and other species are able to live in water that is brackish or, indeed, actually fresh. Rosenvinge (1898, p. 189) pointed out that the upper boundary of the littoral region should be considered as that level at which marine algal vegetation begins, and Börgesen (1905, p. 709) agrees with this view. The littoral region can then best be defined as the zone extending from low-water mark to the highest point where marine algæ cease to grow. As a matter of fact, however, in sheltered waters the upper limit will generally coincide closely with high-tide mark.

The line between the littoral and sublittoral regions is not always easily determined, for conditions vary in different localities. It is not safe to limit arbitrarily the upper boundary of the sublittoral to the lowest water or neap tide mark, for many species characteristic of the sublittoral will grow a little above such a line. Rosenvinge and Börgesen agree in placing the boundary between the littoral and sublittoral somewhat above the lowest tide mark. It is probably very near to the average low-water level.

The lower limit of the sublittoral region varies greatly in its depth from the surface and can not be defined with exactness. It merely marks the gradual diminution of vegetation until a bottom is reached that is devoid of plant life. There is no sharp line showing the lower boundary of the sublittoral, such as defines its upper limit at low-water mark. Consequently there is no line marking the upper limit of an elittoral region or depth from which plant life is absent. Indeed, to speak of an elittoral region is to use a negative expression, and the term is not important in descriptive studies on the distribution of algæ.

The line of greatest significance in determining regions of marine vegetation is that between the littoral and sublittoral, near the level of average low water. Above and below this boundary the life conditions differ more than at any other point between the upper and lower limits of marine algal life. Exposure to the air, to rain, and to the heat and drying influence of untempered sunlight introduce very important factors in the littoral region which are not present in the sublittoral and make this line of separation a most significant one. For these reasons the littoral and sublittoral regions are natural divisions, and further subdivisions are of far less import and, indeed, can hardly be made under ordinary conditions, although some authors have attempted to define a supralittoral region above the littoral.

Certain of the Cyanophyceæ and Chlorophyceæ and a few of the Phæophyceæ and Rhodophyceæ are most commonly found only in the upper region of the sublittoral either just below the lowest tide mark or in shallow water. For these a separate zone might be distinguished; but there are so many species of the Phæophyceæ and Rhodophyceæ which are present in both shallow and deep water that the limits of such a zone, at least in the Woods Hole region, is not easily determined, since there is a very complex overlapping of species. For these reasons we have not attempted to separate and designate regions of the sublittoral further than to qualify the term with the words "upper" or "lower" in certain instances where species are very clearly restricted in their habits.

When the algæ of the littoral and sublittoral regions are studied closely, certain groups of species will be found in more or less close companionship, with definite rela-

tions to such factors as proximity to low-water mark, temperature, exposure to air or to sunlight, sheltered and shaded stations, salinity of water, character of attachment, etc. These groups of species may cover large areas and even form broad zones of vegetation so clearly defined and conspicuous as to deserve the name of *formations;* but the vegetation more often consists of small and scattered groups the limits of which are generally more easily recognized and in which a single species very greatly predominates. These smaller units, usually recognized by the preponderance of a single species, are called by Börgesen (1905, p. 707) *associations*, and we shall employ that term in the brief account that follows.

The regions included in the limits of the Survey do not, on the whole, afford material for a very satisfactory study of algal associations and formations. There is nothing that compares with the picturesque zonation of algæ above and below low-water mark, as illustrated in many localities north of Cape Cod, and such as have been so thoroughly studied by Kjellman, Rosenvinge, and others along the Scandinavian coasts and in Greenland, and by Börgesen for the Faroes. The chief reasons for the comparatively undeveloped character of the formations and associations at Woods Hole and vicinity are four in number: (1) The small tides give a relatively narrow strip of coast line, generally only a few feet wide, available for the development of a littoral flora; (2) a shore line of bowlders, frequently broken by sandy or gravelly beaches, presents no smooth perpendicular or slanting surfaces where the attachment afforded to algæ is uniform in character; (3) the absence of a marked boreal flora, except for the relatively few representatives that are present chiefly in the winter and early spring, deprives the region of a number of species of *Monostroma*, *Alaria*, *Dictyosiphon*, *Fucus*, *Laminaria*, *Sacchoriza*, *Gigartina*, and *Halosaccion*, which are conspicuous north of Cape Cod; and (4) the scraping of the ice along the more sheltered shores effectually prevents the development of a littoral flora in the winter season, which is the most favorable for the growth of green and brown littoral species.

One has only to look at the remarkable plates of Börgesen (1905) illustrating the littoral algal associations and formations along the coasts of the Faroes to realize how poorly developed is the littoral flora at Woods Hole. There are also no rock pools or caverns harboring the striking assemblages of algæ characteristic of such situations. On the other hand, certain peculiarities of bottom, tidal channels, shallow harbors, and coves give conditions and resulting floras that are not present in many northern seas.

The arrangement of the associations follows in general the order of the Catalogue, where will be found the records upon which these brief accounts are based. The number of species discussed or listed is far short of the total list given in the Catalogue; they are merely those sufficiently conspicuous to be worthy of attention in a treatment of algal associations.

For descriptive purposes Buzzards Bay has been regarded in this section of the report as being divided into an upper and lower portion by a line drawn from the west end of Naushon (Robinsons Hole) to Round Hill Point. Vineyard Sound has been divided into three regions, (*a*) the westerly portion from the entrance at Gay Head to a line drawn from the west end of Naushon (Robinsons Hole) to Kopeecon Point, (*b*) the narrow portion from this line to one between Nobska Point and West Chop, and (*c*) the easterly portion from the latter line to one drawn between Falmouth Heights

and East Chop.[a] The lower portion of the Bay and the westerly portion of the Sound have in the summer a flora, here termed the cool-water sublittoral formation, with a number of striking peculiarities, while the more sheltered regions have in the summer a strictly warm-water sublittoral formation.

Only the most striking of the algal associations and formations will be described, for this is a subject which might be followed into such detail that the broad and striking peculiarities would be lost among the minor features. Moreover, for the reasons given above, the physiographical features and other conditions of Woods Hole do not lend themselves to the development of picturesque algal associations.

ALGAL ASSOCIATIONS.

(1) THE LYNGBYA SALT-MARSH ASSOCIATION.

The bottom and sides of shallow bodies of water in salt marshes, and other brackish ditches and pools, are frequently covered by felted growths, which are largely composed of *Lyngbya*, most commonly the species *L. æstuarii* and *L. semiplena*. Mixed with the Lyngbyas may be found *Chroococcus turgidus*, *Microcoleus chthonoplastes*, *Microcoleus tenerrimus*, *Spirulina subsalsa*, *Anabæna torulosa*, *Nodularia Harveyana*, and other forms.

This is a very characteristic association of blue-green algæ frequently forming extensive growths in the summer months in the salt marshes and brackish pools of Quisset, Penzance, and Hadley Harbor.

(2) THE ENTEROMORPHA SALT-MARSH ASSOCIATION.

Brackish pools in salt marshes and other situations frequently contain extensive floating or loosely attached growths, which are chiefly species of *Enteromorpha*, the commonest species being *E. clathrata*, *E. crinita*, *E. percursa*, and *E. prolifera*. *Cladophora expansa* is found under similar conditions, frequently mixed with the Enteromorphas.

This association of green algæ forms surface growths in situations where the *Lyngbya* association is likely to be found over the bottom. It is frequently conspicuous during the summer months in brackish pools of Quisset, Penzance, and Hadley Harbor.

(3) THE CALOTHRIX ASSOCIATION.

Of the four species of *Calothrix* which may be found on stones and woodwork between tide marks, *C. pulvinata* is the most conspicuous, developing thick patches resembling honeycomb on the woodwork of wharves (wharf of U. S. Bureau of Fisheries). *Calothrix scopulorum*, also conspicuous, grows on rocks near high-water mark or above, occasionally in company with *Codiolum gregarium*, forming large indefinite patches; it also grows on piles.

(4) THE RIVULARIA ASSOCIATIONS.

Rivularia nitida is found in salt marshes (as at Quisset) forming thick growths over mud and roots of *Spartina* well above low-water mark. *Rivularia atra* is occasionally plentiful on rocks and barnacles near high-water mark.

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[a] Geographically this region might be considered as a portion of Nantucket Sound if one were disposed to draw an arbitrary line between Vineyard Sound and that body of water.

(5) THE PLEUROCAPSA ASSOCIATION.

Pleurocapsa fuliginosa grows on rocks and stonework, forming a conspicuous dark stain at high-water mark and in depressions wet by waves and spray.

(6) THE ULVA, ENTEROMORPHA, AND MONOSTROMA ASSOCIATIONS.

Rocks and stony beaches above low-water mark frequently exhibit striking growths of species of *Ulva*, *Enteromorpha*, and *Monostroma*. *Ulva Lactuca* var. *rigida* is common above low-water mark on rocks exposed to waves where it frequently forms dense zones of growth. *Enteromorpha intestinalis* is often abundant in quiet waters attached to stones and shells and sometimes to woodwork of wharves between tide marks; it may develop broad zones of growth in such situations. *Enteromorpha linza* is also found in the same situations as *Enteromorpha intestinalis* and is sometimes mixed with it. *Enteromorpha minima* is very common during the spring and summer in situations similar to those of *Enteromorpha intestinalis*, but always growing near high-water mark. In the spring *Monostroma Grevillei* is abundant on stones and larger algæ a little above low-water mark.

These forms, together with certain species of *Cladophora* described in association 9, make up the most characteristic associations of green algæ in the littoral region. They are generally responsible for the conspicuous green zones on wharves, rocks, and beaches above low-water mark.

(7) THE ULOTHRIX ASSOCIATIONS.

Ulothrix flacca is not uncommon in the summer, forming large patches on stones and woodwork of wharves above low-water mark; it is sometimes epiphytic on *Fucus*. *Ulothrix implexa* is also present in the spring on rocks above low water.

(8) THE CHÆTOMORPHA ASSOCIATIONS.

Chætomorpha Linum is common growing in wiry masses over sandy and muddy bottoms. It was dredged by the Survey as deep as 5 fathoms, but is generally found in shallow water in the upper regions of both the cool- and warm-water sublittoral formations (A and B).

Chætomorpha melagonium is present in deeper water off exposed points, such as Gay Head and Cuttyhunk (chart 228). This species was dredged in 4 to 9 fathoms and is a characteristic member of what is here termed the cool-water sublittoral formation.

(9) THE CLADOPHORA ASSOCIATIONS.

Several species of *Cladophora* develop conspicuous associations in the upper level of the sublittoral region. *Cladophora albida* and *C. albida* var. *refracta* form in the summer patches on rocks. *Cladophora arcta* is very abundant in the spring on wharves and harbor walls near low-water mark and below, and is one of the most characteristic of the green algæ at that season. *C. flexuosa* is common in the summer on rocks, and *C. glaucescens*, a delicate species, is also abundant at the same season on rocks and wharves near low-water mark. *C. gracilis* grows luxuriantly during the summer in quiet sheltered waters. *C. lanosa* is epiphytic on larger algæ generally below low water; *C. lanosa* var.

uncialis grows on rocks above and below low-water mark and is conspicuous in the winter and spring. *C. refracta* and *C. Rudolphiana* are frequently abundant on stones near low water and below. *C. rupestris* is a striking species growing off exposed points as at Nobska and Gay Head.

The list of *Cladophoras* in this region is large, but they are apt to grow mixed with other algæ. However, *C. albida*, *C. albida* var. *refracta*, *C. arcta*, *C. gracilis*, and *C. lanosa* var. *uncialis* frequently form extensive and almost pure growths, which are as conspicuous as the zones of *Ulva*, *Enteromorpha*, and *Monostroma*.

(10) THE VAUCHERIA ASSOCIATIONS.

Vaucheria litorea and *V. Thuretii* are occasionally found forming rather extensive and sometimes matted growths over gravel and mud near low-water mark and below.

(11) THE ECTOCARPUS ASSOCIATIONS.

Most of the species of *Ectocarpus* grow attached to larger algæ or to *Zostera*, but some are found on stones and the woodwork of wharves near low-water mark and below. *Ectocarpus confervoides* and *E. siliculosus* are frequently present in the latter situations, forming at times extensive growths. Some of the epiphytic species may grow so thickly over such forms as *Scytosiphon lomentarius*, *Desmarestia aculeata*, *Chordaria flagelliformis*, *Chorda filum*, *Laminaria Agardhii*, and *Zostera* as to form a conspicuous part of the associations that contain these larger algæ and the eel grass. The commonest of the epiphytic species are *Ectocarpus æcidioides* on old *Laminaria*, *E. confervoides* on *Scytosiphon* and *Chordaria*, *E. fasiculatus* on *Chordaria* and *Chorda*, *E. granulosus* on *Sargassum*, *E. penicillatus* on larger algæ and *Zostera*, and *E. siliculosus* on *Scytosiphon*, *Zostera*, etc.

(12) THE CLADOSTEPHUS ASSOCIATION.

Cladostephus verticillatus grows in fairly deep water and has a scattered distribution in Vineyard Sound (chart 229). It was dredged in 2 to 13 fathoms over sandy and stony bottoms. Although not plentiful, this species is conspicuous for its size; it is a member of the warm-water sublittoral formation (B).

(13) THE SPHACELARIA ASSOCIATIONS.

Sphacelaria cirrhosa is epiphytic on *Fucus*, *Ascophyllum*, *Sargassum*, and occasionally on *Zostera;* it may also grow on stones. The species is probably widely distributed along the coast and was dredged in 3 to 8 fathoms on *Sargassum* and stones at several scattered stations in Vineyard Sound.

Sphacelaria radicans is common attached to stones, shells, and mud-covered rocks. It was dredged in 3 to 5 fathoms, chiefly at stations near Vineyard Haven.

The two species are in the warm-water sublittoral formation (B).

(14) THE DESMOTRICHUM AND PUNCTARIA ASSOCIATIONS.

Desmotrichum balticum and *D. undulatum* are common, especially in the spring, forming dense growths on *Zostera;* they are occasionally found on larger algæ and on rocks.

Punctaria latifolia and *P. plantaginea* are likewise common in the spring, the former on *Zostera* and larger algæ, the latter on algæ and rocks.

(15) THE PHYLLITIS AND SCYTOSIPHON ASSOCIATIONS.

Phyllitis fascia is common in the winter and spring on rocks just below low-water mark and in the littoral region. *Scytosiphon lomentarius* is also abundant in similar situations on rocks, and also on stony beaches, where it develops extensive growths during the winter and spring extending above the *Phyllitis* in the littoral region.

These two algæ, so conspicuous in the littoral during the winter and spring, practically disappear during the summer, being then found only in very favorable situations, as, for example, at Gay Head and at Grassy Ledge, in Woods Hole Harbor, on the side of the ship channel. They frequently form a mixed association, but *Scytosiphon* is the commoner of the two and more widely distributed.

(16) THE ARTHROCLADIA ASSOCIATION.

Arthrocladia villosa, which has been considered rather rare, was found by the Survey to be widely distributed in Buzzards Bay and Vineyard Sound (chart 230). Although generally dredged in small quantities, it was obtained in abundance in the cove west of Cuttyhunk Neck (near station 101) July 27, 1905. At this date large plants in full fruit grew on shells and stones in 4 to 5 fathoms, forming large patches over the bottom. The species is a member of the warm-water sublittoral formation (B).

(17) THE DESMARESTIA ASSOCIATION.

Desmarestia aculeata is a large coarse species plentiful in the lower portion of Buzzards Bay and westerly portion of Vineyard Sound (chart 231). It grows over sandy and stony bottoms in 1½ to 14 fathoms. Although the plants are more often scattered, they sometimes form patches which would be considered as associations. The species is frequently a member of the cool-water sublittoral formation (A).

Desmarestia viridis is found not only in the same situations as *D. aculeata*, but also in quieter and warmer regions of the Sound (chart 232). It is common at Woods Hole in the spring and early summer, a little below low-water mark. The growths are generally scattered, but they may also form dense associations. This species is a member of the warm-water sublittoral formation (B), but is also present in colder waters, although not so common there as *Desmarestia aculeata*.

(18) THE DICTYOSIPHON ASSOCIATION.

A species of *Dictyosiphon* is present during the summer months rather widely distributed in both Bay and Sound on stones and over sand in 3 to 10 fathoms (chart 233). The form compares well with material and descriptions of *Dictyosiphon hippuroides*. However, in view of the difficulties in determining species in this genus and the fact that our material was evidently a summer seasonal condition, we do not feel sure of its affinities. It was found at several stations in sufficient quantity to constitute associations, and is present in both the cool- and warm-water sublittoral formations.

(19) THE CASTAGNEA ASSOCIATION.

Castagnea Zosteræ is common at Woods Hole in the summer, attached to *Zostera*. *Castagnea virescens* is occasionally found on rocks, *Zostera*, and larger algæ below low-water mark. Both species are present in the warm-water sublittoral formation (B), but *C. virescens* is also a spring species.

(20) THE CHORDARIA ASSOCIATION.

Chordaria flagelliformis during the summer develops extensive growths on stones and rocks a little below low-water mark. It grows in large masses and is frequently the most conspicuous member of the zone of brown algæ, fringing exposed rocks near low-water mark. The other prominent members of this zone are commonly *Phyllitis fascia* and *Scytosiphon lomentarius*, which grow above the *Chordaria* and in the littoral region. The *Chordaria* is frequently overgrown with *Ectocarpus confervoides*, *E. fasiculatus* or *E. siliculosus*, and it also harbors *Callithamnion Baileyi*, *C. corymbosum*, and other algal epiphytes.

(21) THE MESOGLOIA ASSOCIATION.

Mesogloia divaricata grows in masses on stones and algæ in relatively quiet waters a little below low-water mark. It is a conspicuous summer plant occupying a situation somewhat similar to that of *Chordaria flagelliformis* in more exposed situations.

(22) THE RALFSIA ASSOCIATIONS.

Ralfsia clavata is very abundant on stones and shells at low-water mark and below. It is widely distributed throughout the sublittoral region at Woods Hole and in the Bay and Sound, and has been dredged in 3 to 12 fathoms. *Ralfsia verrucosa* is less widely distributed, but in certain localities has been found in quantity (Grassy Ledge, Little Harbor, Tarpaulin Cove); it grows on stones near low-water mark.

(23) THE CHORDA ASSOCIATION.

Chorda filum is a summer species very common in the sublittoral region on stones and shells in water 3 feet or more in depth. It frequently forms large beds and sometimes supports extensive epiphytic growths of *Ectocarpus fasiculatus*, *Ceramium rubrum*, and other species. *Chorda filum* is widely distributed throughout the Bay and Sound (chart 234) and was dredged in 2 to 14 fathoms.

Chorda tomentosa is a very beautiful spring species common at Woods Hole in the same situation as *Chorda filum*, which takes its place later in the season. We know nothing of its distribution in Buzzards Bay and Vineyard Sound.

(24) THE LAMINARIA ASSOCIATIONS.

The genus *Laminaria* has only three representatives in the waters of Buzzards Bay and Vineyard Sound. In comparison with the flora north of Cape Cod the kelps play but an insignificant part in the vegetation of this region.

Laminaria Agardhii is rather widely distributed (chart 235), being common at Woods Hole on wharves and stones in water 3 feet or more in depth; it was dredged over sandy, shelly, and stony bottoms in 2 to 17 fathoms.

Laminaria Agardhii var. *vittata* is restricted in its distribution chiefly to the lower portion of the Bay and westerly portion of the Sound (chart 236); it grows over sandy, shelly, and stony bottoms in 2 to 17 fathoms, sometimes forming beds of considerable extent frequently mixed with *Laminaria Agardhii*.

Laminaria digitala was found only off Gay Head (chart 237) over sandy and stony bottoms in 3 to 13 fathoms, accompanied by the other forms of *Laminaria*. All of these kelps are characteristic members of the cool-water sublittoral formation (A), but *Laminaria Agardhii* is more widely distributed than the others.

(25) THE FUCUS AND ASCOPHYLLUM ASSOCIATIONS.

Ascophyllum nodosum and *Fucus vesiculosus* are the only rockweeds that develop extensive associations in these waters; the other two species of *Fucus* do not form very conspicuous growths.

Ascophyllum nodosum grows plentifully over rocks near low-water mark and above in somewhat sheltered situations. It is found in its best vegetative condition during the winter snd spring culminating with the fruiting period in May; the summer growth is somewhat dwarfed and much lighter in color (yellowish) where exposed to bright sunlight.

Fucus vesiculosus, with its several forms and varieties, is more plentiful than *Ascophyllum*, growing over a wide zone from below low-water mark to a high point in the littoral region. It is likewise found in its best vegetative condition during the winter and spring, fruiting most abundantly in the latter season. It is represented during the summer by dwarfish growths, frequently lighter in color than the winter condition, except off exposed points as at Gay Head, where the growth and fruiting is more uniform.

The *Ascophyllum* and *Fucus* frequently form a mixed association at Woods Hole, which during the winter develops a broad zone in the littoral region over rocks that are not subjected to severe scraping by the ice. Most of the winter growths matures during the spring and the display during the summer is comparatively poor.

(26) THE SARGASSUM ASSOCIATION.

Sargassum Filipendula is common during the summer in the warmer and more sheltered regions of the Bay and Sound (chart 238); it was dredged over sandy, shelly, and stony bottoms in 2½ to 15 fathoms, sometimes froming rather large beds. At Woods Hole there are conspicuous associations at the entrance to the Eel Pond and off Juniper Point, where the plants grow in large patches in 3 feet to 1 or more fathoms of water. *Sargassum* is thus strictly sublittoral, in sharp contrast to the habits of the species of rockweeds, and it is characteristic of the warm-water sublittoral formation (B).

(27) THE BANGIA ASSOCIATION.

Bangia fusco-purpurea is not uncommon, forming patches on rocks and woodwork of wharves near high-water mark. *Ulothrix flacca* is frequently mixed to a greater or less degree with the *Bangia*.

(28) THE PORPHYRA ASSOCIATION.

Porphyra laciniata frequently develops heavy growths on the harbor walls at Woods Hole near low-water mark. *Porphyra leucosticta* is a spring species common on larger algæ and on *Zostera*.

(29) THE CHANTRANSIA ASSOCIATIONS.

Chantransia virgatula is abundant, fringing the leaves of *Zostera*, and is a conspicuous member of the *Zostera* formation (C). *Chantransia secundata* is sometimes common on *Zostera*, *Ceramium rubrum*, and *Porphyra laciniata*. *Chantransia Thuretii* is occasionally found in quantity on *Ceramium rubrum* and on *Cystoclonium purpurascens* at a depth of 1 to 3 meters (off Juniper Point).

(30) THE NEMALION ASSOCIATION.

Nemalion multifidum is a very characteristic summer species, frequently forming a broad zone on rocks a little above low-water mark. This is, perhaps, the best illustration of a red alga with life habits in this region apparently demanding a certain degree of exposure to the air.

(31) THE ANTITHAMNION ASSOCIATION.

Antithamnion cruciatum proved to be very widely distributed during the summer in Vineyard Sound and Buzzards Bay, attached to stones and larger algæ in 3 to 15 fathoms (chart 239). It frequently forms dense epiphytic growths on *Chondrus*, *Phyllophora*, and *Polyides*. The species is a common member of the warm-water sublittoral formation (B), but it is also found in exposed situations, as off Gay Head and Cuttyhunk. The other species of *Antithamnion* are not found in sufficient quantity to form conspicuous associations.

(32) THE CALLITHAMNION ASSOCIATIONS.

Of the five species of *Callithamnion* found in this region only three forms develop growths so extensive as to be worthy of consideration in this connection.

Callithamnion roseum is common during the summer in the more sheltered waters of the Bay and Sound, growing on stones, shells, larger algæ, and *Zostera* in 3 to 13 fathoms. It is especially abundant in the easterly portion of Vineyard Sound, where *Chondrus*, *Phyllophora*, and *Sargassum* frequently support heavy epiphytic growths. The species is a characteristic member of the warm-water sublittoral formation (B).

Callithamnion Baileyi and *C. Baileyi* var. *laxum* are also common during the summer, but generally only as scattered plants. *Callithamnion Baileyi* grows on rocks, and is also frequently epiphytic on larger algæ, such as *Chordaria* and *Ceramium rubrum*, in the upper level of the sublittoral. It was dredged in 3 to 13 fathoms attached to *Desmarestia*, *Chondrus*, *Phyllophora*, and *Cystoclonium*. The species seems to prefer the conditions of the warm-water sublittoral formation.

(33) THE CERAMIUM ASSOCIATIONS.

Of the six species of *Ceramium* present in these waters, *C. rubrum* deserves the most attention, on account of its abundance and very wide range (chart 240). This species is conspicuous in the upper level of the sublittoral, as one of the commonest members of the zone of red algæ frequently found on rocks a little below low-water mark in company with such forms as *Polysiphonia fibrillosa*, *P. urceolata*, *P. violacea*, and *Chondrus crispus*. *Ceramium rubrum* is also abundant in deeper water, and was

dredged in 1 to 19 fathoms attached to stones. It is a very common epiphyte on *Chorda*, *Chondrus*, and *Phyllophora*, and on *Zostera*. The species is present in both the cool and warm-water sublittoral formations.

Ceramium fastigiatum is frequently abundant on *Zostera* and on larger algæ, such as *Phyllophora*, and sometimes on stones; it was dredged in 2 to 7 fathoms. *Ceramium strictum* and *C. tenuissimum* are also common on *Zostera* and on larger algæ, and occasionally on stones; they were dredged in 2 to 15 fathoms. These three species have a scattered and probably wide distribution in sheltered regions of the Bay and Sound, but are not present in abundance; they belong to the warm-water sublittoral formation (B).

(34) THE GRIFFITHSIA ASSOCIATIONS.

Griffithsia Bornetiana is common in the summer in the more sheltered portions of the Bay and Sound (chart 241). The species is an epiphyte on larger algæ, such as *Chondrus* and *Phyllophora*, and was dredged in 2 to 15 fathoms (most plentiful between 3 and 6 fathoms); it is a conspicuous member of the warm-water sublittoral formation (B).

Griffithsia tenuis has a distribution restricted to the extreme upper portion of Buzzards Bay (chart 242), where it may be found in large patches loosely attached over sandy and muddy bottoms in 2 to 4 fathoms. It is a striking species in these sheltered regions (that support comparatively little algal vegetation), evidently preferring warm waters.

(35) THE PLUMARIA ASSOCIATION.

Plumaria elegans is restricted to exposed situations, such as Gay Head and Sow and Pigs (chart 243). There it is abundant as an epiphyte on *Chondrus* and *Phyllophora* over sandy and stony bottoms in 3 to 17 fathoms. It is one of the most characteristic species of the cool-water sublittoral formation (A).

(36) THE SEIROSPORA ASSOCIATION.

Seirospora Griffithsiana is sometimes very common on stones, shells, *Zostera*, and larger algæ in 3 to 10 fathoms. It has a scattered distribution in both Bay and Sound, and is frequently present in the warm-water sublittoral formation (B).

(37) THE SPERMOTHAMNION ASSOCIATION.

Spermothamnion Turneri is very abundant as an epiphyte on such algæ as *Chondrus*, *Phyllophora*, and *Polyides* in 1 to 17 fathoms, over sandy, shelly, stony, and muddy bottoms. It is distributed widely in the Bay and Sound (chart 244) and is present in both the cool- and warm-water sublittoral formations.

(38) THE SPYRIDIA ASSOCIATIONS.

Spyridia filamentosa is very widely distributed in both Bay and Sound (chart 245); it is found on stones and shells, frequently over muddy bottoms, and on *Zostera* and larger algæ, and was dredged in 3 to 15 fathoms (most plentiful in 4 to 10 fathoms). The species is a characteristic member of the warm-water sublittoral formation (B).

(39) THE CHONDRIA ASSOCIATIONS.

Chondria tenuissima is abundant on rocks and larger algæ below low-water mark along somewhat sheltered shores; it was dredged as deep as 2 to 5 fathoms at Phalarope station 73, but the species is on the whole rather characteristic of the upper level of the sublittoral region. *Chondria tenuissima* var. *Baileyana* is less common, but found in similar situations.

Chondria dasyphylla is also found on rocks and larger algæ and sometimes on *Zostera* below low-water mark. It is a coarse species, generally present in less sheltered situations than *Chondria tenuissima* and was dredged in 4 to 10 fathoms, chiefly in the easterly portion of Vineyard Sound. *Chondria sedifolia* is closely related to *C. dasyphylla*, and has been classed as a variety of the latter; it is less common, but is found in similar situations.

All the species of *Chondria* are members of the warm-water sublittoral formation (B), preferring shallow water and sheltered situations.

(40) THE DASYA ASSOCIATION.

Dasya elegans is very abundant during the late summer below low-water mark, generally in sheltered situations on *Zostera*, on larger algæ, and occasionally on stones; it was dredged over sandy and stony bottoms in 2 to 13 fathoms and has a wide and scattered distribution throughout the Bay and Sound. The species is a member of the warm-water sublittoral formation (B) and is also frequently conspicuous in the *Zostera* formation (C).

(41) THE POLYSIPHONIA ASSOCIATIONS.

Of the 12 species of *Polysiphonia* found in this region 8 are sufficiently common to present conspicuous associations.

Polysiphonia elongata, the largest species, grows on stones and rocks in fairly deep water over sandy, shelly, and stony bottoms in 2 to 17 fathoms (most plentiful in 5 to 13 fathoms). The species is common and widely distributed throughout Vineyard Sound, but is found only in the lower portion of the Bay (chart 246). It is present in both the warm- and cool-water sublittoral formations, but is more plentiful in the latter.

Polysiphonia fibrillosa is common at Woods Hole in the summer, frequently forming a zone on rocks at and just below low-water mark. Although characteristic of the upper region of the warm-water sublittoral, the species was dredged at several scattered stations in Vineyard Sound in 2 to 11 fathoms.

Polysiphonia Harveyi and *P. Olneyi* form tufted growths on eel grass in quiet water, and are members of the *Zostera* formation (C).

Polysiphonia nigrescens is very abundant on stones and shells frequently over muddy bottoms in 1 to 15 fathoms (most plentiful in 5 to 10 fathoms). The species is widely distributed in both Bay and Sound (chart 247), and is present in both the cool- and warm-water sublittoral formations.

Polysiphonia urceolata is abundant in the spring and very conspicuous in the zone of red algæ on stones and wharves below low-water mark. The species at that season is probably widely distibuted in both the Bay and Sound and is then a prominent mem-

ber of the cool-water sublittoral formation; it was dredged in the summer in the lower portion of Buzzards Bay in 2 to 19 fathoms.

Polysiphonia variegata is common in the summer on stones, *Zostera*, and larger algæ, and also grows loosely attached over sand and mud in sheltered situations; it was dredged in 3 to 6 fathoms in the upper portion of Buzzards Bay (chart 248). The species belongs to the warm-water sublittoral formation, preferring sheltered situations.

Polysiphonia violacea is abundant in the summer on stones, rocks, and on the larger algæ below low-water mark; it was dredged in 1 to 13 fathoms over sandy and stony bottoms and has a wide though scattered distribution in the Bay and Sound. The species is an important member of the zone of red algæ below low-water mark on rocks in exposed situations, taking the place which *P. urceolata* occupies in the spring. It belongs to the warm-water sublittoral formation.

(42) THE RHODOMELA ASSOCIATIONS.

Rhodomela Rochei and *R. subfusca* are probably very abundant in the spring throughout the Bay and Sound. The bases of old plants were dredged during the summer at scattered stations in 3 to 8 fathoms for *Rhodomela Rochei*, and 3 to 12 fathoms for *R. subfusca*. In the spring these species are undoubtedly conspicuous members of the cool-water sublittoral formation (A).

(43) THE AHNFELDTIA ASSOCIATION.

Ahnfeldtia plicata is common in exposed situations as off Gay Head and Cuttyhunk (chart 249). It was dredged in 1 to 14 fathoms (most plentiful in 7 to 13 fathoms) over sandy, shelly, and stony bottoms, and is one of the cool-water sublittoral species.

(44) THE CHONDRUS ASSOCIATION.

Chondrus crispus, the Irish moss, is abundant along the shores of the Bay and Sound below low-water mark; it was dredged in 1 to 19 fathoms (most plentiful in 4 to 12 fathoms) over sandy, shelly, and stony bottoms. The species is widely distributed through the Bay and Sound (chart 250), wherever the bottom is favorable, and grows in dense patches on the rocks. It does not as a rule come so close to the surface as *Ceramium rubrum*, *Polysiphonia fibrillosa*, *P. urceolata*, and *P. violacea*, but it is the most conspicuous member on exposed rocks of the zone of red algæ somewhat below these species. *Chondrus crispus* is a very important member of both the cool and warm-water sublittoral formations, with preferences for the former; for, although enduring the warm water of the summer, it grows most luxuriantly in colder temperatures.

(45) THE PHYLLOPHORA ASSOCIATIONS.

The two species of *Phyllophora* have very similar life habits; they are rarely found in the upper level of the sublittoral region and are generally present only at a considerable depth.

Phyllophora Brodiæi grows on stones and in sand and mud and was dredged in 1½ to 15 fathoms (most plentiful in 4 to 10 fathoms). It is distributed very generally

throughout the Bay and Sound (chart 251), but is most abundant off exposed situations, as at Gay Head and Cuttyhunk, where extensive growths are present.

Phyllophora membranifolia is also found on stones and over sand and mud; it was dredged in 3 to 17 fathoms (most plentiful in 4 to 10 fathoms). The species is likewise distributed very generally throughout the Bay and Sound (chart 252), but appears to prefer rather more sheltered situations than *Phyllophora Brodiæi.*

Both species of *Phyllophora* are prominent in the cool- as well as the warm-water sublittoral formations.

(46) THE AGARDHIELLA ASSOCIATION.

Agardhiella tenera is very common on stones and shells in fairly deep water; it grows in 2 to 15 fathoms (most plentiful in 4 to 10 fathoms). The species is very widely distributed throughout both the Bay and Sound (chart 253), but prefers rather sheltered waters and is a characteristic member of the warm-water sublittoral formation (B), where it is commonly associated with *Grinnellia americana.*

(47) THE CYSTOCLONIUM ASSOCIATIONS.

Cystoclonium purpurascens has a scattered distribution in both Bay and Sound (chart 254). It was found in 2½ to 13 fathoms (most plentiful in 4 to 10 fathoms) attached to stones over sandy, shelly, and stony bottoms, occasionally over mud. The species rarely forms extensive patches but is conspicuous because of its large size; it is found in both the cool- and warm-water sublittoral formations.

Cystoclonium purpurascens var. *cirrhosum* is abundant in the lower portion of the Bay and westerly portion of the Sound (chart 255). It was dredged in 1 to 17 fathoms (most plentiful in 4 to 12 fathoms) attached to stones and to larger algæ over a bottom similar to that of the preceding species. The variety is much more luxuriant than the species and frequently forms large patches of vegetation; it clearly prefers the conditions of the cool-water sublittoral and is a prominent member of that formation (A).

(48) THE CHAMPIA ASSOCIATION.

Champia parvula is one of the most widely distributed algæ of the region, occasionally forming extensive patches in the Bay and Sound (chart 256). It grows in 1 to 19 fathoms (most plentiful in 4 to 12 fathoms) attached to stones, *Zostera*, and larger algæ, over sandy, shelly, stony, and muddy bottoms; it is frequently found in shallow water along the shore. The species belongs to the warm-water sublittoral formation (B), being found most abundantly in sheltered regions.

(49) THE LOMENTARIA ASSOCIATIONS.

Lomentaria rosea is found only off the exposed points of Gay Head and Cuttyhunk (chart 257). It was dredged in 4 to 13 fathoms on stones, shells, and on larger algæ, over sandy, shelly, and stony bottoms. The species is restricted to the cool-water sublittoral and although never abundant is one of the most characteristic members of this formation (A).

Lomentaria uncinata grows in the sheltered waters of the Bay and Sound (chart 258). It was dredged in 1½ to 15 fathoms (most plentiful in 4 to 10 fathoms) over sandy,

shelly, and stony bottoms, and it is also abundant in shallow water along shore. In sharp contrast to *L. rosea*, this species is characteristic of the warm-water sublittoral formation (B) and prefers sheltered situations where it frequently accompanies *Champia parvula*.

(50) THE RHODYMENIA ASSOCIATION.

Rhodymenia palmata, the dulse, is found chiefly in the lower portion of Buzzards Bay and westerly portion of Vineyard Sound (chart 259). It was dredged in 1 to 19 fathoms (most plentiful in 4 to 12 fathoms) growing on stones and larger algæ, over sandy, shelly, and stony bottoms. A prominent member of the cool-water sublittoral formation (A), this large species is conspicuous for its size, although the growths in this region are never extensive.

(51) THE DELESSERIA ASSOCIATION.

Delesseria sinuosa is practically restricted to the lower portion of the Bay and westerly portion of the Sound (chart 260). It grows on larger algæ, such as *Chondrus* and *Phyllophora*, occasionally on stones, and was dredged in 1½ to 17 fathoms (most plentiful in 4 to 12 fathoms). The species is a member of the small group of algæ peculiar to the exposed conditions off Gay Head and Cuttyhunk, and is one of the noteworthy forms in the cool-water sublittoral formation (A).

(52) THE GRINNELLIA ASSOCIATION.

Grinnellia americana is almost universally distributed throughout the Bay and Sound (chart 261). It was dredged in 2 to 19 fathoms (most plentiful in 4 to 12 fathoms) on stones and shells, over sandy, shelly, stony, and muddy bottoms, but it likewise comes close to the surface, as on piles of wharves (Little Harbor, Woods Hole). Although apparently in all regions of the sublittoral, this species is partial to the more sheltered situations, and consequently warmer waters, where it is one of the most characteristic and abundant forms together with *Agardhiella tenera* and *Champia parvula*.

(53) THE POLYIDES ASSOCIATION.

Polyides rotundus, although never abundant, has a rather wide distribution in both the Bay and Sound (chart 262). It is found only in fairly deep water, 1½ to 15 fathoms (most plentiful in 4 to 10 fathoms), over sandy, shelly, and stony bottoms, occasionally over mud. The species is a member of both the cool- and warm-water sublittoral formations, and is conspicuous for its size, although the plants grow in scattered groups.

(54) THE CORALLINA ASSOCIATION.

Corallina officinalis grows in dense patches over rocks in exposed situations below low-water mark and to a considerable depth; the species is widely distributed in the more open portions of the Bay and Sound (chart 263). It was dredged in 4 to 10 fathoms, over sandy, shelly, and stony bottoms. The associations of *Corallina* are generally so dense that they occupy the surface of their attachment to the almost complete exclusion of other algæ; the species is present in both the cool- and warm-water sublittoral formations.

(55) THE HILDENBRANDIA ASSOCIATION.

Hildenbrandia prototypus is common on stones and rocks near low-water mark and extending into deep water, where it grows in 1½ to 14 fathoms (most plentiful in 4 to 10 fathoms); it is widely distributed in the Bay and Sound (chart 264). The species is found in both the cool- and warm-water sublittoral formations.

(56) THE LITHOTHAMNION ASSOCIATION.

Lithothamnion polymorphum grows on stones and shells in fairly deep water and is rather widely distributed in the Bay and Sound (chart 265). It was dredged in 2 to 15 fathoms (most plentiful in 4 to 10 fathoms) over sandy, shelly, and stony bottoms. *Lithothamnion*, although never found in abundance, is present in both the cool- and warm-water sublittoral formations.

(57) THE MELOBESIA ASSOCIATIONS.

Melobesia farinosa is fairly common on *Fucus vesiculosus*, *Chondrus*, *Phyllophora*, and *Zostera* at low-water mark and below, being dredged in 3½ to 11½ fathoms, at scattered stations in the Sound. The species is a member of the warm-water sublittoral formation.

Melobesia Lejolisii is very abundant on *Zostera* throughout the Bay and Sound in both shallow and deep water; it was dredged in 2 to 12½ fathoms. The species prefers rather sheltered waters, where it may cover the eel grass with a thin incrustation; it is characteristic of the *Zostera* formation.

Melobesia membranacea is occasionally found on *Chondrus* and *Phyllophora*, generally in exposed situations as off Gay Head, Cuttyhunk, and Penikese. It was dredged in 3½ to 10 fathoms and clearly belongs to the cool-water sublittoral formation.

Melobesia pustulata is common on *Ascophyllum*, *Chondrus*, and *Phyllophora*, and is present in both shallow and deep water, being dredged in 1½ to 14 fathoms off Gay Head, Cuttyhunk, and in the easterly portion of the Sound. The species has a scattered and probably rather general distribution along the shore and is a member of both the cool- and warm-water sublittoral formations.

THE COOL-WATER SUBLITTORAL FORMATION.

The cool-water sublittoral formation of the summer contains a number of very interesting and characteristic algæ, some of which are limited in their distribution to the exposed waters off Gay Head and the reefs of Sow and Pigs. Other species have a more extended range throughout the lower portion of Buzzards Bay and the westerly portion of Vineyard Sound. Finally there is a group of species which, while most abundant in the regions described above, are also found in other portions of the Bay and Sound, where they form a part of the sublittoral flora characteristic of these more sheltered, and in the summer, warmer waters.

The species in these lists preceded by an asterisk (*) are the larger or more abundant forms which dominate the formation; species which are rare or occasional are followed by an (o).

The most interesting and noteworthy species in this formation are those which are especially characteristic of the cold waters north of Cape Cod and have been recorded only

south of the cape in exposed situations where they may be expected to find conditions approaching those of the north coast. The list is as follows:

*Chætomorpha melagonium.	Actinococcus peltæformis (o).	*Rhodymenia palmata.
*Laminaria digitata.	Gymnogongrus norvegicus (o).	*Delesseria sinuosa.
*Plumaria elegans.	Euthora cristata (o).	Melobesia membranacea (o).
Rhodomela subfusca.	*Lomentaria rosea.	

Another group of species comprises those which range both north and south of Cape Cod; many of them are conspicuous in the warm-water sublittoral formation (B). The following are prominent:

Chætomorpha linum.	Chorda filum.	*Phyllophora membranifolia.
Cladophora albida var. refracta.	*Laminaria Agardhii.	Agardhiella tenera.
C. gracilis.	*L. Agardhii var. vittata.	*Cystoclonium purpurascens.
C. rupestris.	*Ceramium rubrum.	*Cystoclonium purpurascens var. cirrhosum.
Ectocarpus confervoides.	Polysiphonia atrorubescens (o).	Grinnellia americana.
E. fasciculatus.	*P. elongata.	Polyides rotundus.
E. siliculosus.	*P. nigrescens.	Corallina officinalis.
*Desmarestia aculeata.	P. nigrescens var. fucoides (o).	Hildenbrandia prototypus.
*D. viridis.	P. urceolata.	Lithothamnion polymorphum.
*Dictyosiphon hippuroides.	Actinococcus subcutaneus.	Melobesia membranacea.
*Chordaria flagelliformis.	*Ahnfeldtia plicata.	M. pustulata.
Leathesia difformis.	*Chondrus crispus.	
*Ralfsia clavata.	*Phyllophora Brodiæi.	

Finally there is a group of species which are widely distributed in the warm-water sublittoral. Chief among them are—

Cladostephus verticillatus.	*Spermothamnion Turneri.
*Antithamnion cruciatum.	Rhodomela Rochei.

The lists of species in the genera *Cladophora* and *Ectocarpus* are undoubtedly far from complete, for studies at other seasons of the year would be expected to give many additions. It must be remembered that we know nothing of this formation in the lower portion of Buzzards Bay and the westerly portion of Vineyard Sound in the winter and spring when the conditions are much more favorable for the support of a cool-water sublittoral flora.

The chief factor which determines the cool-water sublittoral formation is the relatively low temperature of the bottom water during the summer months. The records of the temperatures off Gay Head and Cuttyhunk for the summer, as well as for other seasons of the year, are presented in a table on page 450, to which the reader is referred. It is probable that the lowest winter temperatures of the bottom water at these points fall somewhat below 35°, and that the highest summer temperatures are close to 60°. This represents about the yearly range of the bottom temperatures off the exposed points of Gay Head and Sow and Pigs, and in general of the extreme westerly portion of Vineyard Sound and the deeper water of the lower portion of Buzzards Bay. The cool-water sublittoral formation may then be said to endure a maximum temperature of about 60° for a short period in midsummer, but to live for most of the year at temperatures considerably lower. Its most favorable temperature is perhaps close to 50° or below. Whether essentially the same formation is present during the winter is not known, but it seems very probable.

THE WARM-WATER SUBLITTORAL FORMATION.

A characteristic warm-water sublittoral formation is present during the summer in the more sheltered regions of the Bay and Sound—that is, in the upper portion of Buzzards Bay and in the narrow and easterly portions of Vineyard Sound. The conditions in these regions are much more varied than in the lower portion of the Bay and the westerly portion of the Sound occupied by the cool-water sublittoral formation. For example, the conditions and flora of the upper end of Buzzards Bay are quite different from those around Woods Hole. Further subdivisions of the warm-water sublittoral formation could undoubtedly be made to advantage, but it would be unwise to attempt to do so on our present information. Accordingly, we shall treat the warm-water sublittoral as a very large and widely distributed formation, excluding, however, those algæ which are characteristically associated with beds of *Zostera* in an assemblage called here the *Zostera* formation (C).

The species in these lists (as in those of the cool-water sublittoral formation) preceded by an asterisk (*) are the larger or more abundant forms which dominate the formation; species which are rare or occasional are followed by an (o).

The most interesting and noteworthy species in the warm-water sublittoral formation are those which have not been reported at all north of Cape Cod or are present there only under exceptional conditions. This list includes the following species:

Cladophora albida.
Ectocarpus granulosus var. tenuis (o).
E. lutosus (o).
E. Mitchellæ (o).
Cladostephus spongiosus (o).
*C. verticillatus.
Rhadinocladia Farlowii (o).
Striaria attenuata (o).
*Arthrocladia villosa.
Elachista stellaris var. Chordæ (o).
Myriactis pulvinata var. minor.
Stilophora rhizodes (o).
Sargassum bacciferum (o, floating in Sound).
*S. Filipendula.
S. Filipendula var. subedentatum.
Scinaia furcellata.
*Antithamnion cruciatum.
A. cruciatum var. radicans (o).
A. plumula (o).
Callithamnion Baileyi var. laxum.
*C. roseum.
C. tetragonum.
Ceramium botryocarpum (o).
C. capri-cornu (o).
*C. tenuissimum.
*Griffithsia tenuis.
Pleonosporium Borreri.
*Seirospora Griffithsiana.
*Spermothamnion Turneri.
*Spyridia filamentosa.
Chondria dasyphylla.
C. sedifolia (o).
*Polysiphonia fibrillosa.
P. vestita (o).
Rhodomela Rochei.
R. virgata (o).
Actinococcus aggregatus (o).
Gymnogongrus Griffithsiæ (o).
Gracilaria confervoides (o).
G. multipartita.
G. multipartita var. angustissima (o).
Hypnea muciformis.
Lithothamnion polymorphum.

Another group of species comprises those which range both north and south of Cape Cod, some of them being also conspicuous in the cool-water sublittoral formation (A). The list includes the following:

Chætomorpha linum.
Cladophora albida var. refracta.
C. arcta.
C. glaucescens.
C. gracilis.
C. hirta (o).
C. lanosa.
C. Rudolphiana.
C. rupestris.
Bryopsis hypnoides (o).
B. plumosa (o).
*Ectocarpus confervoides.
*E. fasciculatus.
E. granulosus.
*E. siliculosus.
E. siliculosus var. hiemalis (o).
Pylaiella littoralis.
Sphacelaria cirrhosa.
S. radicans.
Punctaria plantaginea (o).
Desmarestia aculeata (o).
*Desmarestia viridis.
Dictyosiphon hippuroides.
Myriotrichia filiformis.

Castagnea virescens.
*Chordaria flagelliformis.
*Leathesia difformis.
*Mesogloia divaricata.
*Ralfsia clavata.
*Chorda filum.
Laminaria Agardhii.
Laminaria Agardhii var. vittata (o).
Antithamnion americanum (o).
Callithamnion Baileyi.
C. byssoideum.
C. corymbosum.
*Ceramium rubrum.
*C. strictum.
*Griffithsia Bornetiana.
*Chondria tenuissima.
C. tenuissima var. Baileyana.
*Dasya elegans.
Polysiphonia elongata.
P. fastigiata (o).
*P. nigrescens.
*P. variegata.
*P. violacea.
Actinococcus subcutaneus.
Ahnfeldtia plicata.
*Chondrus crispus.
*Phyllophora Brodiæi.
P. Brodiæi var. catenata (o).
*P. membranifolia.
Sterrocolax decipiens (o).
*Agardhiella tenera.
Cystoclonium purpurascens.
C. purpurascens var. cirrhosum (o).
*Champia parvula.
*Lomentaria uncinata.
Rhodymenia palmata (o).
*Grinnellia americana.
Gloiosiphonia capillaris (o).
Polyides rotundus.
Corallina officinalis.
Hildenbrandia prototypus.
Melobesia farinosa.
M. membranacea (o).
M. pustulata.

The warm-water sublittoral formation of the summer is known not only from the dredgings in the deeper waters, but also from many observations in the shallow waters at a number of points at or near Woods Hole, where the algal flora along shore has been studied by the writer for some ten summers. Extensive studies along shore have not been possible in the regions of the cool-water sublittoral formation (that is, in the lower portion of Buzzards Bay and westerly portion of Vineyard Sound), and the flora of the shallow water is known only at a few points, such as Gay Head, portions of Cuttyhunk, and Penikese.

It is interesting to note that a considerable number of species in the above lists are restricted wholly or largely to shallow water in a zone from low-water mark to a depth of 3 to 6 feet. The characteristic algæ in this zone of the upper warm-water sublittoral are:

Chætomorpha linum.
Cladophora, the species in the above lists.
Ectocarpus, the species in the above lists.
Pylaiella littoralis.
Sphacelaria cirrhosum.
S. radicans.
Punctaria plantiginea.
Castagnea virescens.
Chordaria flagelliformis.
Leathesia difformis.
Mesogloia divaricata.
Ralfsia clavata.
Chorda filum.
Callithamnion Baileyi.
C. Baileyi var. laxum.
Ceramium rubrum.
Chondria dasyphylla.
C. sedifolia.
C. tenuissima.
C. tenuissima var. Baileyana.
Polysiphonia fastigiata.
P. fibrillosa.
P. variegata.
P. violacea.
Chondrus crispus.
Champia parvula.
Lomentaria uncinata.
Grinnellia americana (on piles).
Melobesia farinosa.
M. pustulata.

The algæ listed in the *Zostera* formation (c) may also properly be included in this, the upper warm-water sublittoral formation.

The summer temperature of the water is undoubtedly the chief factor in determining the warm-water sublittoral formation as a whole. The degree of exposure to wave action or tide currents and the character of the attachment are of course important factors affecting the local distribution of the algæ along the shores. Thus, the vegetation off exposed points, as at Nobska or on the ledges in the passage of Woods Hole, is subjected to conditions very different from those of neighboring sheltered coves. As stated before, the summer temperature in Great Harbor, Woods Hole (as shown by daily averages

covering the years 1902–1906), passes 60° F. about June 1, holds between 69° and 71° from about July 11 to August 28, and passes 60° in its autumn decline about October 12. The bottom temperatures were taken at a large number of stations in both the Bay and the Sound during the month of August. They were at this time highest in the upper portion of Buzzards Bay, where 71.3° was recorded, while in Vineyard Sound 68.8° was recorded off Falmouth, and 66.9° off the west end of the Middle Ground, these temperatures becoming in general lower toward the mouth of Buzzards Bay and the westerly portion of Vineyard Sound. The warm-water sublittoral formation may, then, be said to endure a temperature of about 70° for midsummer, and its most favorable temperature is perhaps close to 60° or above, although many species live in colder water. It would be very interesting to know to what degree the place of the warm-water sublittoral is taken by representatives of the cool-water sublittoral as the temperature of the water falls during the autumn. The cool-water sublittoral might be expected to invade the narrow and easterly portion of Vineyard Sound and the upper portion of Buzzards Bay, but we have no data on this problem.

THE ZOSTERA FORMATION.

There are a number of algæ which have the habit of growing frequently or invariably attached to *Zostera*. They, together with the eel grass itself, constitute a very clearly defined assemblage which is here called the *Zostera* formation. It is really a specialized region of the warm-water sublittoral formation, for the eel grass vegetates during the summer when the water is warm. Many of the species listed below will consequently be found in the lists of the latter formation (B).

Zostera marina, the eel grass, is very abundant in all sheltered regions of both Bay and Sound, forming thick beds in shallow waters. It was frequently found at inshore stations of the survey, and also at scattered stations in deeper waters of the Bay and Sound (chart 266), being dredged in 2 to 13 fathoms, over sandy, stony, and muddy bottoms. The eel grass, however, prefers shallow water in coves and bays or along sheltered coasts, where it grows luxuriantly, developing extensive beds in depths of 2 feet to 2 fathoms or more. Under these conditions the formation described below is frequently developed to a greater or less extent. Species preceded by the asterisk are the most important forms; those which are rare or occasional are designated by (O).

When the *Zostera* grows in very quiet and shallow waters the blue-green alga, *Anabæna torulosa*, is common on the mud at the base of the plants, frequently breaking loose and floating on the surface as slimy masses. *Lyngbya majuscula* sometimes forms extensive tufted growths and, breaking free, also floats on the surface. Other blue-green algæ in the *Lyngbya* salt-marsh association (1) may be present. *Hydrocoleum glutinosum* and *Glœocystis zostericola* form coatings on the leaves, and *Enteromorpha clathrata*, *E. plumosa*, with other species, and sometimes species of *Cladophora*, grow in loosely attached masses. These algæ are all forms which may be expected in brackish water.

When the eel grass grows in more open or exposed situations the list of epiphytes includes species which are never found in brackish water. Among these the following are conspicuous:

*Cladophora gracilis and occasionally other species.
Ascocyclus orbicularis (o).
*Ectocarpus confervoides.
E. penicillatus.
*E. siliculosus.
Sphacelaria cirrhosa (o).
*Desmotrichum balticum (in the spring).
*D. undulatum (in the spring),
Pogotrichum filiforme (o).
*Punctaria latifolia.
Rhadinocladia Farlowii (o).
Giraudia sphacelarioides (o).
Castagnea virescens (o).
*C. Zosteræ.
Hecatonema maculans (o).
Myrionema vulgare.
Stilophora rhizodes (o).
Erythrotrichia ceramicola.
*Porphyra leucosticta (in the spring).
Chantransia secundata.
*C. virgatula.
Antithamnion cruciatum (in deep water).
Callithamnion Baileyi.
C. Baileyi var. laxum.
*C. byssoideum.
*C. corymbosum.
*C. roseum.
*Ceramium fastigiatum.
C. rubrum.
*C. strictum.
*C. tenuissimum.
*Seirospora Griffithsiana.
*Spyridia filamentosa (o).
Chondria dasyphylla (o).
Chondria sedifolia (o).
*Dasya elegans.
*Polysiphonia Harveyi.
*P. Olneyi.
P. variegata (o).
Rhododermis Georgii (o).
Melobesia farinosa.
*M. Lejolisii.

The *Zostera* formation endures temperatures considerably higher than those given for the range of the warm-water sublittoral, especially where the eel grass grows in coves or other sheltered stations. Such waters may remain above 70° F. for many days, probably at times reaching as high as 75° to 78°. These conditions as to heat are the most extreme of any in this region, except of course the small brackish pools and ditches of the salt marshes.

A WINTER SUBLITTORAL FORMATION.

It is clear that, as the temperature of the Bay and Sound falls during the autumn, the conditions become less favorable for the warm-water sublittoral flora. Many species characteristic of waters south of Cape Cod pass out of season, although certain species which may be said to endure the summer's heat are at their best in the winter season. A cold-water winter sublittoral formation is thus developed, which extends throughout the Bay and Sound, reaching its best development probably in the late winter and early spring.

We know nothing of this winter and spring flora in the deeper waters of the Bay and Sound, for there have been no dredgings for algæ at these seasons. The cool-water sublittoral formation of the lower portion of the Bay and westerly portion of the Sound would be expected to enter the more sheltered regions occupied by the warm-water sublittoral during the summer, but how far it may extend is a matter of conjecture. Undoubtedly species appear which are not present in either Bay or Sound during the summer, some probably developing from resting spores that carry the forms through the summer, and others coming in by means of spores brought from a distance.

It is probable that numbers of northern species, the spores of which might be brought from a distance, would be able to establish themselves, develop to maturity, and perhaps pass through several generations before the temperature rises sufficiently in the spring to put an end to their growth. Species of *Cladophora*, *Ectocarpus*, and other rapidly growing green and brown algæ, reproducing by zoospores, are admirably fitted for a periodical winter invasion, and some of the smaller red algæ which mature quickly would also be expected to take part in such a migration.

Some observations on the algal vegetation along shore in shallow water have been made during the winter and spring, and if these are indices of the general change through-

out the sublittoral, the flora of the bottom of the Bay and Sound must be very different indeed from that of the summer. Especially interesting are the series of studies of the flora of Spindle Rocks, Woods Hole, which were made at intervals throughout a 12-month cycle in 1904 and 1905. These are described in the next section of this paper. Such intensive studies over long periods of time are very much to be desired to determine the seasonal changes in algal floras.

We give below a list of the algæ so far known to be present in the cold-water sublittoral formation of the winter and spring:

Monostroma Grevillei.
Ulva Lactuca.
Chætomorpha Linum.
Cladophora arcta.
C. lanosa.
C. lanosa var. uncialis.
Derbesia vaucheriæformis.
Ectocarpus æcidioides.
E. confervoides.
E. elegans.
E. fasciculatus.
E. granulosus.
E. ovatus.
E. penicillatus.
E. siliculosus.
E. tomentosus.
Pylaiella littoralis.
Sorocarpus uvæformis.
Asperococcus echinatus.
Desmotrichum balticum.
D. undulatum.
Pogotrichum filiforme.
Punctaria latifolia.
P. plantaginea.
Desmarestia viridis.
Dictyosiphon fœniculaceus.
Giraudia sphacelarioides.
Castagnea virescens.
Chordaria flagelliformis.
Hecatonema maculans.
Myrionema corunnæ.
M. vulgare.
Chorda tomentosa.
Laminaria Agardhii.
Haplospora globosa.
Scaphospora Kingii.
Erythrotrichia ceramicola.
Porphyra laciniata.
P. leucosticta.
Chantransia secundata.
C. virgatula.
Antithamnion americanum.
Callithamnion Baileyi.
Ceramium rubrum.
Polysiphonia fastigiata.
P. nigrescens.
P. urceolata.
Rhodomela Rochei.
R. subfusca.
Ahnfeldtia plicata.
Chondrus crispus.
Sterrocolax decipiens.
Rhodymenia palmata.
Gloiosiphonia capillaris.
Rhododermis Georgii.

The cold-water sublittoral formation accepts a winter temperature, which for at least two and a half months probably averages under 35° F., as indicated by the records for Great Harbor, Woods Hole (the average temperature between December 25 and March 15 for the years 1902–1906 was below 35°). Many of the species of this formation reach their best vegetative condition and fruit during the spring, and then pass out of season. During this period the temperature of the water rises steadily, passing 60° about June 1.

THE LITTORAL FORMATIONS.

As has been stated before, the algal growths in the littoral region are not very striking in the immediate vicinity of Woods Hole, chiefly for these reasons, (1) that the tides are small, (2) that the shore line is very broken, (3) a marked boreal flora is absent, and (4) the scraping of floating ice in the winter prevents the development of an extensive littoral flora at this season. Neighboring coasts exposed sufficiently as to be free from floating ice, as at Cuttyhunk, have heavy growths of algæ in the winter, but there have been no opportunities for thorough studies at this season. These growths are, however, undoubtedly composed largely of rockweeds (*Fucus* and *Ascophyllum*).

The littoral formations of the different seasons at Woods Hole are of a very spotted character, rarely being so extensive as to attract attention and generally breaking up at once into small associations. Of these the following are at times very evident: The *Calothrix* associations (3), the *Rivularia* associations (4), the *Pleurocapsa* association

(5), the *Ulva*, *Enteromorpha*, and *Monostroma* associations (6), the *Ulothrix* associations (7), the *Phyllitis* and *Scytosiphon* associations (15), the *Fucus* and *Ascophyllum* associations (25), the *Bangia* association (27), the *Porphyra* association (28), the *Nemalion* association (30).

THE PLANKTON.

The only studies on the plant life present in the plankton of the region covered by the survey have been those of Peck (1894 and 1896), chiefly in relation to its value as a source of food, especially for the menhaden. In his second paper Peck (1896, p. 356) records his observations on the plankton of Buzzards Bay, describing and figuring a number of microorganisms belonging to the Peridinales and Bacillariales (Diatomales), together with animal forms. His studies were quantitative rather than qualitative, and the identification of his material as regards plant life was only partial, but it is clear that the plankton of these regions is very abundant and widespread, as would be expected of warm, shallow bodies of water.